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OCEAN WATER COLOR ASSESSMENT FROM ERTS-1 RBV AND MSS IMAGERY

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16. Abstract

Experiment is to divide ERTS-1 RBV-1 image into two new images by photographic masking, to isolate spectral scene reflectances in the 465-490 nm and 490-580 nm regions, as an index of ocean water blue/green color ratios. Cessation of RBV coverage and lack of ground truth for images of original test site have re-oriented experiment to other areas where large blue/green color differences exist, to prove technique feasibility. Progress has been made in correcting residual stationary RBV radiometric shading errors as part of this project.

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PREFACE

The objective of the experiment is to separate spectral scene reflectances of ocean water recorded in the ERTS-1 RBV-1 band, 465-580 nm, into two new images; one representing blueish water color approximately in the 465-490 nm band, and the second in the 490-580 nm green region. This will be done by photographic masking with RBV-2 and MSS-4 images from the same set. By normalization, density measurements made on the water in the two new images should indicate relative blue/green water color ratios, and give some indication of potential water fertility.

Ground truth on water color was not available for the original test site during the period of ERTS-1 RBV coverage, and other areas are being examined where large water color differences are known to exist, to test process feasibility. One area, in the Caribbean, is being worked on.

Residual stationary radiometric shading correction errors in the RBV images have been a problem, partially corrected by masking.

At this state final conclusions and recommendations would be premature.

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1.0 INTRODUCTION

1.1 The objective of this work is to determine if the image resulting from the blueish part of the ERTS-1 Return Beam Vidicon Camera 1 (RBV-1) response can be isolated from the green portion of its total spectral response by photographic masking with the Multispectral Scanner (MSS-4) green record. The RBV-1 records in the 465 nm - 580 nm region, while MSS-4 responds in the 490 nm - 600 nm band. The 25 nm difference between the two sensors in the shorter wavelength region lies in a blueish, or cyan part of the spectrum associated with clear, barren ocean water, while in the longer wavelength regions suspended biological and inert materials tend to give the water a greenish color. Isolation and comparison of relative densities in the blue and green portions of the RBV-1 image, if successful, would permit blue/green water color ratios to be found and, from this, some indication of potential water fertility. Originally, it was proposed to validate this process with ground truth water color data collected from selected ocean areas at the time of ERTS-1 coverage.

1.2 The cessation of RBV image acquisition in August 1972 has severely limited the location and number of images to work with. It was also found that large residual shading errors were inherent in the RBV images. While procedures were found for reducing the errors substantially, their magnitude was such that it was likely that only large differences in the blue/green ratios could be detected with any confidence. These factors coupled with a lack of water color ground truth collection in the available image areas has re-oriented the experiment toward demonstrating that at least large differences in the blue/green ratios could be detected. Also, if the approach is to be successful, it was found that some scene gamma correction will be necessary to correct for atmospheric effects in relating scene irradiances of the RBV-1 and MSS-4 bands to the MSS-5 band during masking.

1.3 A new Data Handling Plan was therefore submitted 30 Mar 1973 and has been approved; basically it is proposed to use the techniques originally suggested, but with RBV/MSS images of ocean areas where strong blue and green water color differences are known to exist. Three regions are under examination, the Caribbean/Bahamas Islands, San Diego/San Clemente Island, California, and the Gulf Stream track off the Florida coast. Work has started on the Caribbean area. Apollo and Gemini and high altitude aircraft natural color images of these areas will be used to confirm regional water color differences.

2.0 INTERACTIVE IMAGE MASKING PROCESSES

2.1 In this experiment a number of photographic reproduction processes are used, which involve careful sensitometric control over image densities, gammas, and positive and negative masks. To clarify for this and subsequent reports how and why these steps are taken, a brief review follows of input image characteristics and image processing techniques.

2.2 Atmospheric Effects and ERTS-1 Images. The ERTS-1 photographic images supplied to the user are reproduced at γ=1.0; that is, at the apparent scene contrast received at the sensor position. Atmospheric scattering of sunlight into non-image haze light is more prominent in the green than in the red and infrared regions, and reduces the scene contrast in a non-linear way, low scene radiances being more affected than higher values. The absolute effect of haze is seldom known for a given set of images, but a way of estimating it is necessary if a green ERTS-1 record is to be compared with a red ERTS image on terms of relative scene reflectance. This can be done by measuring the density differences between dark and light areas in the two spectral scenes which have known, or closely estimated reflectance values in the respective bands. For example, a calm water surface clear of sunglitter, reflects about 5% of incident sunlight at sun elevations above 50^{o} in the blue through the near infrared spectral regions, while upwelling blue-green light in deep calm water may only add a few percent to the reflected surface light in that spectral region. In the red record, the negative image of the deep water would have little density since no upwelling red light is present and would print dark in the positive. In the green spectral negative the water should also have little density, but it is found that irradiance from the scattered hazelight in the atmospheric path has added a considerable density to the negative, and the same area will appear much lighter in the green positive print. The increased negative density found in the green region versus that in the red or infrared can be used to estimate the effect of atmospheric haze, and its compression of scene contrast. (1, 2) Clouds, and white beach can be used as highlight references, where atmospheric scattering has the least effect, to normalize the density ranges of the two images to a common base.

2.3 As ERTS-1 images are also reproduced within a closely controlled density range, as well as gamma factor, direct sensitometric normalization of densities and relative scene reflectances is facilitated. Spot density checks on highlights and corrections for base-fog densities are necessary, however. Also, low scene radiances which are recorded at less than 25% of sensor response are reproduced at gamma less than 1.0. This must be considered when working with low scene radiances.

2.4 RBV Residual Shading Errors in Radiometric Correction. In starting work with the RBV images it was discovered that residual vidicon shading errors existed in the RBV-1 and -2 images. By photographic masking, these were largely reduced.(3) A positive RBV-1 image of a scene of interest was masked with a negative RBV-1 image taken over the open ocean. The negative was matched in gamma and density range with the positive to suppress the uneven densities caused by shading errors during subsequent re-printing. The same treatment is being applied to RBV-2 images.

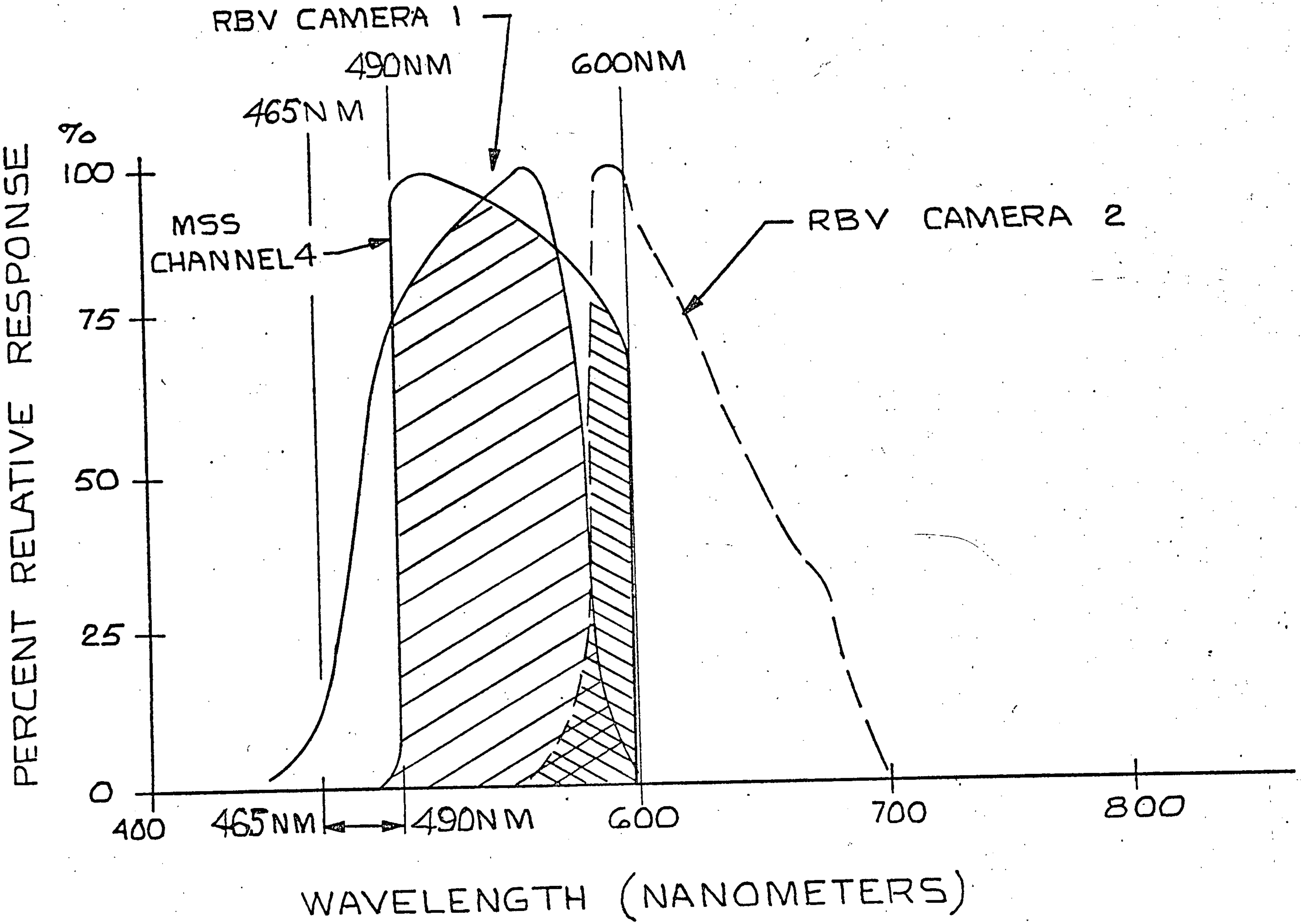
2.5 Masking for Spectral Isolation of 465-490 nm Band. Figure 1 shows the basic approach in isolating the 465-490 nm band from the RBV-1 image. MSS-4 negative, 490-600 nm, is registered with an RBV-2 positive image and printed to a new negative which now represents a 490-580 nm spectral band with the 580-600 nm yellow record removed. This negative is registered with the RBV-1 465-580 nm positive, and printed to produce a negative which now has the 465-490 nm scene reflectances,(A). This negative is registered with the RBV-1 original positive and printed to make a new negative, which now includes only the 490-580 nm scene reflectances, (B). (A) and (B) respectively represent the blueish and green spectral regions in the original RBV-1 image. A schematic is shown in Figure 2.

2.6 To produce usable results by this technique the RBV images must be corrected for residual radiometric shading errors, and the RBV-1 and MSS-4 images should be corrected for scene gamma compression.

3.0 WORK IN PROGRESS AND SCHEDULED

3.1 Images for this experiment were not received until late in 1972, but preliminary work was done with ERTS images from other sources. When images for the project were received, masking techniques were developed for reducing residual RBV shading errors, and were applied to images of the original test area, Monterey Bay, California. Useful ground truth on water color data could not be obtained for the period of RBV coverage of the area, nor could any positive water color differences be confirmed from these images.

3.2 ERTS-1 image set 1007-15165 30 Jul 72 is currently being worked on. This set covers the northern part of the Great Bahama Bank, Northwest Providence Channel, part to Grand Bahama Island, and west to part of the Florida coast. Water color, as evidenced in Apollo and Gemini natural color images which are also being examined, ranges from deep blue to light green. Some sensitometric data are available for these images. Through color separation and density measurement the relative



RBV CAMERA 1
490NM
600NM
465NM
%
100
75
50
25
0
MSS
CHANNEL4
RBV CAMERA 2
PERCENT RELATIVE RESPONSE
400
465NM
490NM
600
700
800
WAVELENGTH (NANOMETERS)

FIGURE 1

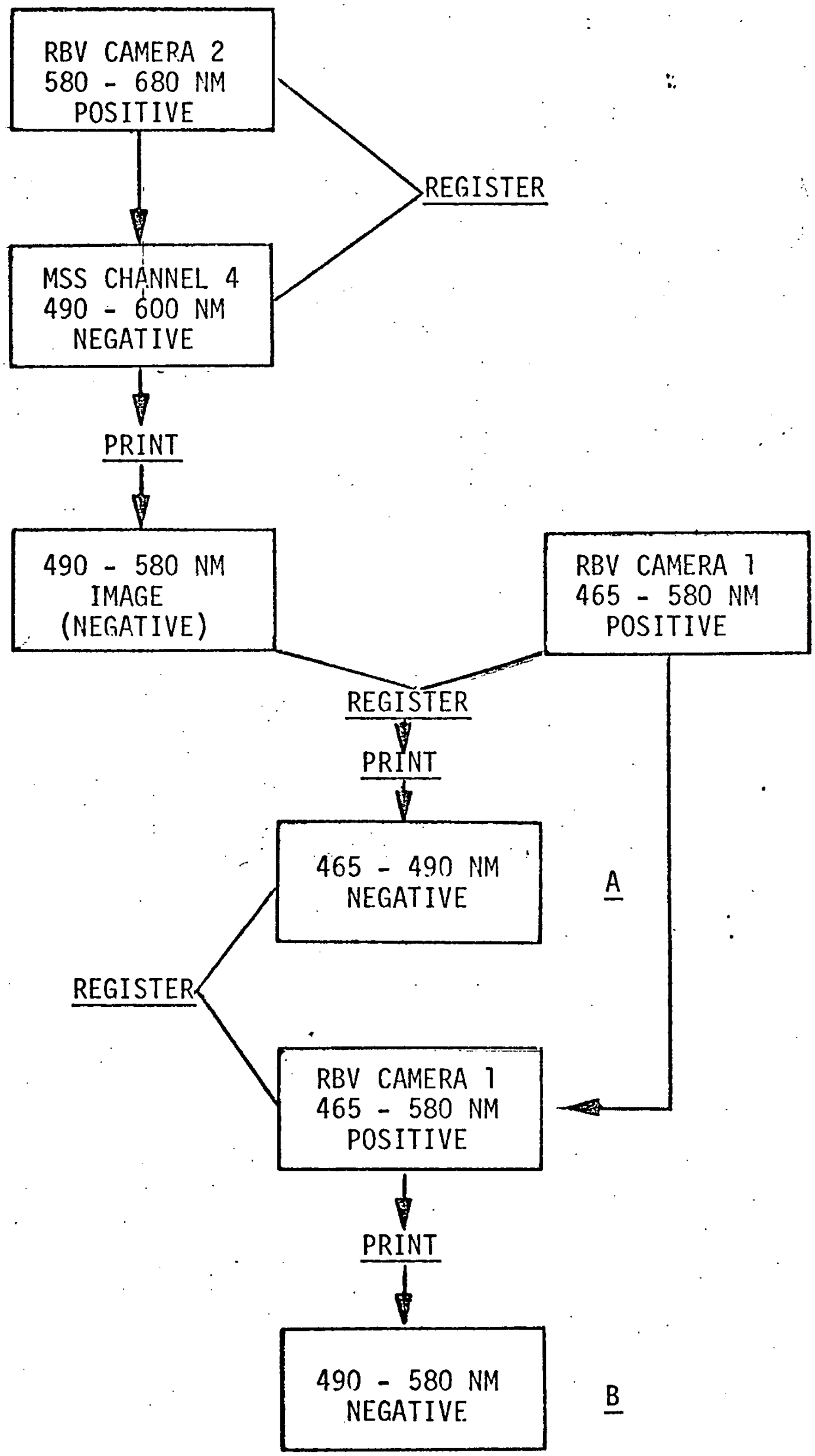


Figure 2 MASKING SCHEMATIC

order of blue/green color ratios may be determined to provide a form of ground truth for the large color differences which exist in this region.

3.3 Since it is desired to isolate and compare the 465-490 nm and 490-580 nm records in the color film with similar regions in the ERTS RBV-1 images, special color filters will be used for color separating the Gemini and Apollo images selected.

3.4 Scene gamma correction has been given the MSS-4 image on a tentative basis, using the MSS-5, -6 and -7 as primary references for water reflectance in the deep water areas, for low scene radiances. Subject to further study ground scene gamma in the MSS-4 image appears to be degraded from a nominal $\gamma=1.0$ down to 0.25. The corrected image has been reproduced at $\gamma=4.0 \left(\frac{1.0}{0.25}=4.0\right)$. Similar treatment will be given the RBV-1 image, masked for residual shading errors, to restore it to a nominal ground level $\gamma=1.0$. The masking processes shown in the schematic in Figure 2 will then be carried out.

3.5 Comparison of the relative density ratios in the ERTS-1 RBV-1 (A) and (B) images, and their relation to density differences obtained in the color separations made from the Gemini/Apollo images, will then be made. If correlation is found, it is planned to use the same techniques on images where water color differences are not as large as the Caribbean; the Gulf Stream area may provide a subject, if suitable images can be found.

4.0 PROGRESS SUMMARY

4.1 The large residual, stationary shading errors found in the RBV images make it uncertain that, even when corrected by the techniques described in reference (3), very small blue/green color differences can be discriminated in deep water as an index to fertility. In the images of the Caribbean/Bahamas Banks being worked with, the large color differences observed are caused primarily by the high proportion of green spectral energy reflected from the bottom in the shallow areas relative to the blue, while only a few percent of green upwelling light is found in the deep water, and the color is predominantly blue.

4.2 Progress is being made in showing that the blue and green components of RBV-1 can be isolated, and should be demonstrated during the next reporting period. From the data produced, an estimate of the potential utility of the technique should be possible.

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